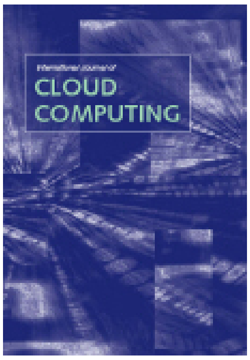

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Impact of internet of things in social and agricultural domains in rural sector: a case study

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Impact of internet of things in social and agricultural domains in rural sector: a case study

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Abstract: The term internet of things (IoT) in general connects various types of things/objects to the internet with the help of various information perception devices towards exchanging information. In this case, data can be considered as one of the most valuable aspects of internet of things. Accordingly, the data linked to internet of things have specific characteristics towards modernising and improving the technologies associated with relational-based database management. As, there is huge increase of devices, the amount of data generated are also be too large, the main intention is to organise the large amount of data to build a new future of computing into a globally connected network. It is obvious to face the challenges through better sensing and monitoring of production through internet of things understanding the specific farming conditions. This paper aims at providing and implementing adaptive, efficient remote and logistic operations by actuators to realise dynamic semantic integration.

Keywords: sensor; actuator; internet; logistic operations.

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1 Introduction

In general, there are many constraints and challenges towards realising the development in rural sectors which are required to monitor and integrate almost all the infrastructure as well as services specifying the intelligence. The advancement along with application of internet of things (IoT) in the rural sector linked with virtual platform will have provision to process and integrate the virtual infrastructure analysing the tools, monitoring equipment, storage, within the system. Sometimes the application of IoT is towards smart billing as well as data analytics in energy management. Similarly, system associated with waste collection linked with cloud-based IoT services may support dynamic scheduling and routing. The essential services required in the rural sectors are not limited to mobile medical services, education system, sanitation, water management system, waste management, road system, inter village connectivity, lighting control, digital literacy, agro processing as well as agriculture services. While focusing on application of IoT in rural sector, it is required to concentrate on support value-added services lined to application domains. Primarily, it is required to focus on waste, energy and water management and accordingly the system has the primary role towards technological advancement and automation. Hence, it is responsible to optimise the system performance and minimise the expenses through improved process efficiency. Also, monitoring the components can be improved through implementation of sensors along with real time data.

The terminologies associated with applications of IoT and will be defined as follows:

- *6LoWPAN:* It will unify the current version of the internet protocol with low-power wireless personal area networks. It may have the ability of transmission of information with the devices.
- *Advanced encryption standard:* This standard was established in the year 2001. It is associated with the public as well as a private key system, along with the aspects of implementing the encryption.
- *Application programming interface:* It is the platform linked to the point of integration.
- *Bluetooth low energy:* It is also termed as Bluetooth 4.0. Being wireless, and having low power consumption, it will allow the objects to transmit data.
- *Embedded software:* Implementing the software, the codes associated with the system will be executed through hardware microcontrollers. Specifically, machine level instructions are implemented without using any operating system.
- *Gateway:* It is the specific location that receives information from many other locations on the network and transmits information to another network.
- *General packet radio service:* It is termed as wireless communication standard that supports a number of bandwidths and provides data rates of 56–114 kbps.
- *Machine to machine:* It is linked to the technology linked with one connected device to communicate and exchange information with other connected device, without any interference.

- *Media access control:* In this control mechanism, it allows the physical medium to be organised to pass data back and forth.
- *LORA protocol:* This specification enables the IoT and machine to machine architecture towards wireless communication and transmission.

This paper provides a study on the application and impact of IoT in social and agricultural domains in rural sector. The rest of the paper is organised in various sections, where, Section 2 deals with some related works of literature, Section 3 is describing the requirement of the same in the rural areas, Section 4 is having implementation details of the same, Section 5 results and analysis, Section 6 future directions and finally the paper is concluded in Section 7.

2 Review of literature

Selective works on similar domain from the literature are picked up in order to draw an impression on the current developments in use and impact of IoT in social and agricultural domains. The same is presented below.

Miller and Mork (2013) in their work have focused regarding the requirement of digital information through the internet. As such, the incremental growth linked to production may require the application of digital technologies to process and store the data linked to data centres.

Dupont et al. (2012) during their study have discussed the mechanism to minimise power consumption. In fact, the standard approaches to resource over provisioning may be essential towards implementation of dynamic virtual machine techniques. These may be able to minimise the implementation and usage of energy without compromising any service level agreement. Being familiar, and with the continuously growing trends, the consumption of energy may be well evaluated implementing the virtual machine techniques.

Bolla et al. (2011) in their work focused on implementation of fifth generation (5G) wireless cellular network technology, so as to support the drastic demands of user subscriptions and data bandwidths. It has also been focused towards major challenges related to green communication technologies. Accordingly, the IoT application may be essential as standard requirement to be processed automatically. Gandotra and Jha (2017) in their work focused on smart farming sector which may be termed as precision agriculture. They tried to clarify the basic objectives linked to precision agriculture applying enabled information technology to supervise the soil and crop conditions.

Aubert et al. (2012) in their work have defined the design principle of IoT along with the platform to accumulate environmental data and store in the virtual environment. Jayaraman et al. (2016) in their study have focused on smart farming applications linked to monitor the applications associated with arm vehicle tracking, along with monitoring the greenhouse. They have visualised the condition of farmers and usefulness of the soil sensors to reconcile the issue and produce better crops. Ilapakurti and Vuppalapati (2015) during their study have focused on performance on several parameters linked to greenhouse using Zigbee-based wireless communications. The usage and implementation of IoT gateways have been observed in continuous scenario and the authors also tried to focus on remote agriculture process automation.

Liu et al. (2015) in their work provided a comprehensive survey and issues of adoption of the IoT. Onyalo et al. (2015) in their work have focused on advantages and practicability of the IoT technologies towards sustainable development of rural area and also projected towards applications in the agriculture domain. They also focused on some very specific requirements of rural areas. Dlodlo and Kalezhi (2015) during their study focused on frugal IoT infrastructure towards monitoring the small scale industries and enhance the quality. They also tried to minimise IoT related hardware deployment, while maximising the benefits of the adoption of such hardware may be responsible to improve the prospects for food security. Fleming et al. (2016) during their study have discussed usability and implementation of standalone wireless sensor network for precision irrigation well connected with internet along with ZigBee-based wireless sensor network through a GPRS modem. The terminals linked with the sensors may be empowered through solar panels, and provided with on-board sensors able to measure soil temperature and soil moisture to automate the field watering process. Mafuta et al. (2013) in their work have focused on challenges related to soil and fertiliser management. They tried to clarify the impacts of fertilising products on the soil. Ibrahim et al. (2015) during their study focused green IoT concepts linked to billions of things equipped with sensing, processing, and wireless communication capabilities and also may require energy provided by on-board batteries.

Shaikh et al. (2017) in their work have focused on IoT technologies to provide potential solutions to resolve issues of traceability, visibility and controllability. These IoT technologies may be instrumental to enhance the quality. In such case, IoT may play a role in resolving the issues of food quality and safety and provide useful information to the beneficiaries. Gu et al. (2012) during their work focused on implementation mechanisms of IoT technologies with different distributed resources. Considering the concept, the resources of IoT may be categorised under different layers.

Stoyanova (2020) discusses digitalisation technologies in building and property management. These areas relate to rural sector and the management of agricultural buildings and agricultural machinery. The lack is between high IT and the proper application. Vasilev and Stoyanova (2019) analyse the process of information sharing among partners in supply chains. IoT generate new data which has to be sent to logistics partners in supply chains. Thus the formal description of the sent logistics information together with data form IoT is crucial for data management in enterprises.

Vasilev and Kehayova-Stoycheva (2019) describe the extension of desktop ERP systems by providing mobile access. Data generated from IoT should be integrated in existing ERP systems. This issue is very complex. It is not widely discussed. Its theoretical background should be created along with application in business.

3 Requirements for rural sector

Practically, the rural sectors must be facilitated with minimum infrastructure like transportation medium, water supply along with power and internet facilities. In this regard, the importance may be given to design and signify the ecosystem in the rural sectors. Accordingly, education and technology may be provided to supplement the indigenous skills, and to ensure the digital and awareness to information technology along with skilling interventions to the society. Also it may be required to provide better education and healthcare, optimised energy management, sanitation, and security management towards growth in rural sectors. While utilising and managing power, it may be difficult towards control operations linked with the power grid and may be required to enhance security associated with grid and reliability. Broadly speaking, managing power may be the process of monitoring, controlling, and conserving energy in the system. Accordingly, the strategies may be defined to optimise the energy by monitoring and quantifying the routine energy waste, used time and critical implementation. Similarly, while implementing, IoT to the irrigation system, it must be analysed that, the outcomes of the agricultural system sometimes may be dependent towards the effective irrigation system. As per the survey, around 85% of the fresh water may be utilised and dependent towards the population. It is seen that, the agricultural scenario may be dependent towards irrigation management and accordingly it may be required to optimise irrigation.

As per the survey, it has been seen that in rural areas, the accumulation of waste products along with the conventional bins in general may depend on the population which may need automation. Accordingly, the sensors interfaced waste bins may be thought of aiming to use the cloud interfaced network to automate the waste bins along with managing the waste collection, and it may be possible introducing the concept of smart bins linked to sensors and monitored through centralised hub. All the relevant data may be received through the sensors and attributes may be monitored with full accessibility. Considering the services in the village sectors, technically it may be required to incorporate non-interoperability of the heterogeneous technologies with IoT concepts and make realisation of unified rural scale ICT platform.

In a general sense, the rural IoT is responsible with a provision to monitor the energy consumption and optimise as per requirement. So, it is possible to identify the main energy consumption sources and to set priorities for optimisation. It may also be essential to exploit the increased number of connected spots to provide Wi-Fi connection to villagers. In addition, a fault detection system will be easily realised on top of the street light controllers.

Assuming the IoT services associated to villages are based on a centralised architecture, the heterogeneous set of peripheral devices can be thought of to accumulate various types of data with optimisation. The data generation will be handled through various technologies and aggregated data then will be again optimised. Moreover, various data have security, privacy, and quality requirements. The communication between sensors and from sensors will be deployed through Wi-Fi technology, linked to the base station as well as strong internet connection. So the sensor will accumulate the information from the existing environment and data will be transferred to cloud storage.

4 IoT in social and agricultural domains in India and Poland

In India, agriculture is considered as the primary concern and mostly responsible towards economic growth. But, in many times, due to change of weather condition or may be heavy, intense storm and heat waves, it affects severely and the productivity can be decreased to a greater extent. To overcome from the specific problem and to minimise the hurdles in the field of agriculture, enhancing the productivity, the transformed technologies associated with the IoT can be adopted to enable farmers to compete with the enormous challenges. Also, the technological involvement and its usability will have to be enhanced and cultivated for agriculture sector.

In such scenario, the farmers will be provided with the information about the agricultural products using the sensors based on IoT so that there will be a continual growth in agricultural logistics.

Also in Polish agriculture, there is a very large potential for the application of technologies in the area of the IoT. The technological revolution in this sector is a necessity. There are around 1.4 million farms in Poland, so the potential for using such solutions is very large (Pak, 2019).

It is worth mentioning that on 24 August 2018, the working group on the IoT was established in Poland with a task to identifying actions necessary to create conditions for the development of IoT technologies, so that they could have a real impact on Poland's economic growth. As a result of the work, a report (Ministerstwo Cyfryzacji, 2019) was prepared, which indicates the scope of the possible use of IoT, including agriculture, food safety and environmental protection, which are presented below:

1 Agriculture
   - Managing the use of fertilisers and plant protection products.
   - Water use management in agricultural production/precision irrigation.
   - Optimisation of fertilisation/precise fertilisation.
   - Monitoring of pests and weeds threatening crops, environmental conditions – the use of sensors in the cultivation and breeding and protection of plants, animal husbandry, and supervision of growth phases.
   - Precise feeding.
   - Tracking inventory.
   - Waste management and recycling in agricultural production.
   - Management and monitoring of the apiary economy.
   - Climate control in horticultural production under covers as well as technological parameters in cold stores, storage rooms and dryers.

2 Food safety
   - Monitoring the food supply chain (farmer, food processor, logistics and warehousing, retailer, and consumer – combining relevant data generated at each stage).

3 Environmental protection
   - Air quality monitoring, including suspended particulates, toxic gases (e.g., NO_2, O_3, CO) and volatile organic compounds (VOC), carbon dioxide and potential emission sites.
   - Monitoring the intensity of ionising radiation.
   - Continuous monitoring of potential sources of air pollution, e.g., factories and production plants.
   - Monitoring of the quality and quantity of water and the occurrence of algal blooms.
   - Monitoring of soil quality and horticultural substrates.
   - Noise monitoring in the natural environment and in urban areas.

- Monitoring of biodiversity, habitat status.
- Monitoring in waste management.

As a result of the work carried out, the subgroup identified the following barriers:

- Lack of coverage with open LPWAN wireless networks.
- Lack of education regarding the possibilities and solutions of IoT in agriculture, giving real benefits.
- Lack of demonstration farms, which can be an example of solutions for the use of the IoT.

In order to develop IoT in agriculture, the following actions have been proposed:

- Support for activities aimed at covering the whole country area with the reach of wireless communication networks in technology appropriate for IoT devices with battery supply (e.g., LoRaWAN, Weightless, Sigfox, and NB-IoT). In the case of agricultural applications and environmental protection (sparsely populated areas with a small number of base stations), an infrastructure is needed to connect a sufficient number of devices – including sensors working for months or years on battery power. This infrastructure should be available not only in the B2B model for large companies, it should also support the SME sector. In order to make business decisions (in the field of analytics or optimisation, insurance) it is necessary to provide a sufficient amount of constantly updated data.
- Creation of publicly available resources of climatic and hydrological information with high mesh density at the level of public administration – this is real data from weather stations, measurement points, not just simulations and forecasts.
- Guaranteeing access to data from many sources. Open and free access to national system resources (including historical data). The high accuracy and timeliness of the data is important. In the case of creating new databases, mechanisms should be provided to inform about the reliability/accuracy ratio of a given data source (including, e.g., aging of sensors). It is suggested to provide financing for public entities in the field of providing and maintaining such bases and raising the competences of institutions in this field. An element of the infrastructure is also the IT part related to the storage and processing of data. The methodology of data collection, data interoperability and the ability to aggregate data from various sources for analytical purposes and the application of existing, open standards in this respect are important. Data from national databases (carried out by public entities) should be available to users free of charge.
- Financial support for reference installations – demonstration farms (e.g., belonging to agricultural advisory centres that have direct contact with customers – farmers), support for pilot programs in the field of IoT. It is suggested to create a legal framework for public-private partnerships that provide the ability to easily test and demonstrate business ideas.

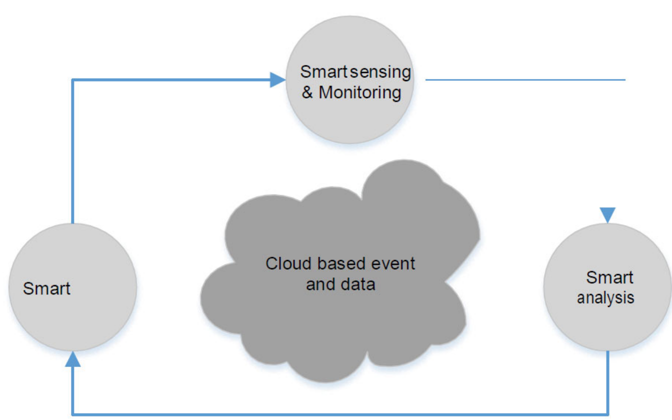
- Creating institutional forms of financial support for IoT projects of special social importance (where profit is not a priority): for example, smog monitoring infrastructure (dense network of air quality sensors in cities, sensors on chimneys, production plants, communication routes), IoT application in measurements drought, in the beekeeping economy, breeding, support for the rational use of plant protection products and fertilisers in agricultural production.
- Development of subsidised forms of education in the field of digital economy, including IoT. Education in the field of IoT technology for institutions such as agricultural advisory centres, scientific institutes related to agriculture, and natural universities (for knowledge propagators) (Ministerstwo Cyfryzacji, 2019).

4.1 Challenges associated in agriculture sector

Similar challenges are identified which are found to be crucial for developing such systems for agricultural sector in India and Poland:

- insufficient production information
- minimal awareness and visualisation towards weather forecast
- insufficient information towards soil as well as crop analysis
- ignorance towards information and communication technology and lack of awareness among farmers about the benefits of ICT in agriculture
- unpredictable weather condition.

Figure 1 The concept of intelligent agriculture as an information and physical management system (see online version for colours)



Source: Own elaboration based on Mackowiak (2019)

Figure 1 summarises the concept of intelligent agriculture as an IT and physical management system, which means that smart devices – connected to the internet – control the functioning of the farm. Intelligent devices cooperate with conventional tools (e.g., rain gauge, tractor, technological line) through all kinds of sensors, capable of performing independent actions or doing it remotely. The figure shows that smart systems play an important role in control, and people analyse and plan actions. However, it can be expected, that the human role in analysis and planning will be increasingly supported by machines, as a result of which the IT-physical cycle will become almost independent of people. People will always get involved in the whole process, but more and more often they will achieve a much higher level of efficiency, leaving most operational activities to the machines (Mackowiak, 2019).

5 Implementation details

In the agriculture sector, many people are still being unaware about implementation mechanism of IoT particularly in agriculture sector. In this article, it is being intended to focus the performances of various operations along with the system linked with IoT equipped with various sensors for measuring different environmental parameters. The primary concern in this work is to execute tasks such as moisture sensing, soil testing, measuring atmospheric pressure and temperature along with performance indication by moving forward or backward and switching electric motor.

The experiment has been conducted on an agricultural land within the institutional campus of Gandhi Institute for Education and Technology, Baniatangi, Dist. Khordha, Odisha India. The land is found suitable for the experiment, as it is completely surrounded by traditional agricultural fields, far away from the urban area. It was conducted during the month of April 2019. Sensors were installed in various locations of the land with regular intervals. Various components of the experimental setup are discussed below:

5.1 Basic controller device

It is an open-source-based hardware and software consisting of a circuit board, programmed, conceptualised as microcontroller with supporting software. Also, the integrated development environment can be implemented through circuit. In such case, sensors associated with soil, temperature and rainfall can be connected to store the details about the relevant sector. It can then be connected to the controller, so that the data is linked to the motor.

5.2 Moisture sensor

It is applied to detect the moisture of soil to check whether there is be water around the sensor, so that it may be useful towards agriculture. It can be simply inserted into the soil and capture the data. The sensor linked to sense the soil moisture uses capacitance to measure the water content of soil by implementing the dielectric permittivity of the soil.

5.3 Soil pH sensor

The soil pH sensor can be used to measure the soil nature. It is understood that the plant roots in general absorb mineral nutrients such as nitrogen and iron as soon as they are dissolved in water. The high accuracy humidity and temperature sensor may provide the calibrated, linearised sensor signals. These also have capacitive type humidity sensing signals yielding unmatched sensor performance.

5.4 Ultrasonic sensor

It is used to detect the level in the system. Accordingly, the system can be implemented in two levels, i.e., ground water level and surface water level. The surface water level indicates the amount of water level that must be maintained above the ground for a crop. The ground water level indicates the amount of water present inside the soil.

5.5 Algorithm to analyse sensor mechanism

Input: Arduino board, 10 kohm photo resistor, 220 ohm resistor, built-in LED, baud rate 9600, single-chip USB to serial (RS232), transmitter and receiver (TXD and RXD), MODEM control pins (RTS, CTS, DTR, DSR, DCD, and RI)

Output: PIR sensor sends either 0 for detecting or 1 for detecting initial values, and IR sensor sends either 0 for detecting or 1 for detecting processed values

```
1    START
2    Assign the temperature as well as humidity sensor
3    Initialise the sensor device and obtain the sensor value
4    Define and link the sensor pins associated with the sensor
     device
5    Define the serial_input device linked to the sensor device
     and set the position
6    Set the position of the motor pin device with sensorled_pin
     and obtain the data
7    Compare the data with data obtained from serial_device and
     initiate the retrieval process
8    Iterate the process with motor_pin device and check the
     parameters of the sensors
9    Initialise the sensor data and link to sensorled_pin
10   Compare the data of sensorled_pin with serial_device data
11   Obtain the value of sensor_pin and check the parameter of
     the sensor
12   Categorise the sensors and obtain the values of serial
     device (temperature, humidity, moisture)
13   Map the value of serial device from 0 to 550
14   If (humidityvalue > 10)
       set sensorinput_device to high (i.e., approx 500)
     Else
       set sensorinput_device to low (i.e., approx 0)
     End
15   If (sensor_device.value <= 50)
       set sensorinput_device to medium (i.e., approx. 300)
     Else
       set sensorinput_device_temperature to low (i.e., approx.
       0)
     End
```

```
16  Obtain the data from sensorinput_device and compare with the
    value of serial device
17  If match occurs, then
      set the motorinput_device towards actuator
    Else
      Reinitiate the process to obtain new set of data
    End
18  STOP
```

5.6 Algorithm for sensors and data accumulation

Input: Arduino board, 10 kohm photo resistor, 220 ohm resistor, built in LED, baud rate 9600, single-chip USB to serial (RS232), transmitter and receiver (TXD and RXD), MODEM control pins (RTS, CTS, DTR, DSR, DCD, and RI)

Output: The sensors will initiate 0 for detecting initial values and 1 for detecting processed values

```
1   START
2   Assign the Arduino, serial module and crystal display device
3   Initialise the pin values
4   Categorise the sensor pins
5   Validate the sensor pins as per the serial module device
6   Reinitiate the sensor data and assign to the sensor device
7   Accumulate the data associated with humidity, soil, moisture
8   Obtain the data associated with light sensor
9   Optimise the data by comparing its analogue values
10  Obtain the humidity level and compare the data with sensor
    device
11  Regenerate the moisture content and soil data, validate the
    sensor pins
```

Finally, the obtained data have been fed to MATLAB 13b for further analysis and result generation.

6 Results and analysis

As per the accumulation of sensor data, it is observed that the maximum variation of atmospheric temperature is approximately 27% along with the humidity level 23%. Similarly, the variation of sensor data linked to soil moisture is 16% along with the soil pH 10%. In this work, it is intended to accumulate and analyse all the data from various sensors like temperature, humidity, moisture along with other environmental factors. In such situation, the system will be associated with several units at different geographical position to accumulate data and transmit to the desired platform focusing on environmental factors. Results from this experiment are presented below:

6.1 Results

Table 1 Atmospheric pressure in time frame

No. of devices included	*Time (ms)*	*Atmospheric pressure (psi)*
20	0.02	7.23
20	0.04	7.14
20	0.06	7.12
20	0.07	7.11

Figure 2 Atmospheric pressure vs. time (see online version for colours)

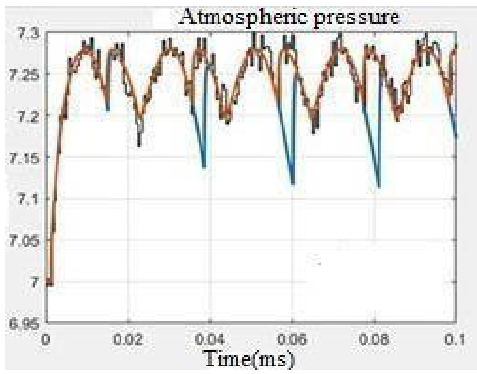


Figure 3 Performance indicator vs. time slot (see online version for colours)

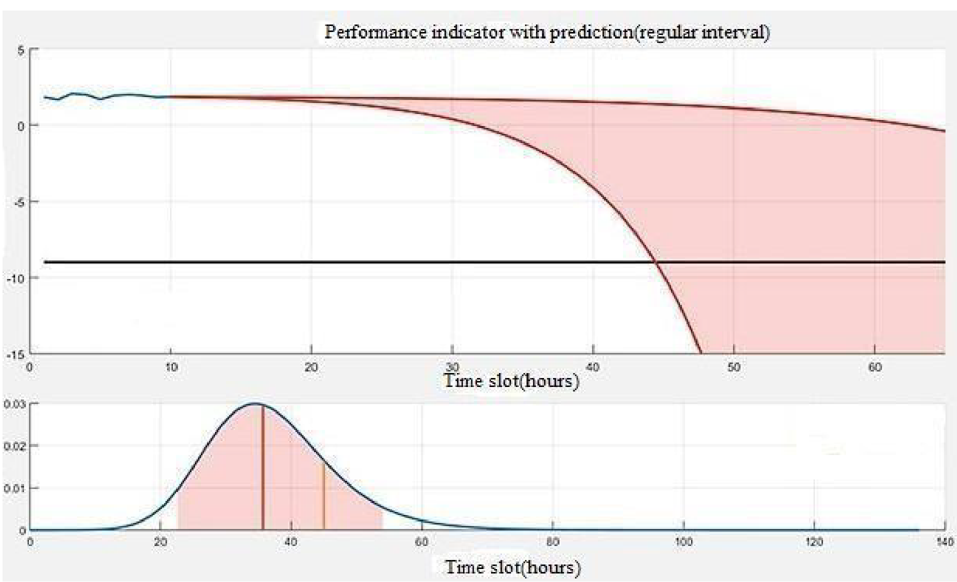


Table 2 Performance indicator with moisture level

No. of devices included	*Time slot (hr.)*	*Moisture level (%)*	*PI (30 min interval)*
20	10	30	0.014
20	20	34	0.019
20	30	45	0.027
20	37	47	0.029

6.2 Experimental analysis

The values of temperature, humidity and moisture parameters are projected along with performance indicator in regular interval. The parameters are according to the time slots and linked to the data associated with temperature, humidity and moisture. As per the figure, it is observed the clear picture of the changes in the values with respect to date and time. As soon as the value reaches the threshold value the Wi-Fi module will generate response. If the moisture value is 0 the motor will have to be switched on. When the moisture value reaches 1, the moisture content in the field is good and the motor will have to be switched off. It is noted that while managing the irrigation systems in efficient manner, soil moisture measurement is very essential. The individuals linked with agriculture will be in a position to improve the quality of the crop by better management of soil moisture.

7 Discussion and future direction

In the present scenario, the agriculture is gradually replaced and enhanced by appropriate and accurate digital system. To perform the agriculture in smart as well as innovative way, implementation of IoT is more essential using smart sensors. Accordingly, IoT will be instrumental to enable towards monitoring the agricultural activities and to enhance the productivity of the crop. Sensors of different types will be used to collect the information of crop conditions and environmental changes and inform the farmers as well as device to initiate corrective actions. The system can further be improved by incorporating new self-learning techniques to be deployed in the cloud to recognise the behaviour of the sensing data. Also the sensors will be used to detect and transmit the real time pictures by integrating it with other information.

8 Conclusions

The IoT devices implemented in the system will provide to some extent near optimal or automated solution for data acquisition from sensors deployed in the field. As it is obvious that the farmers may not be aware of technology and agricultural practices, so it is essential for them to take preventive measures to reduce the losses in agriculture. The application linked to the sensing layer of the IoT technology will be shared through the network and application layers of the IoT technology. The idea towards implementation of IoT for agriculture will be more suitable approach to achieve optimality. Accordingly, the IoT platform will take into account not only the environmental component but also the local economic and social aspects. Also the system will be cheaper and efficient as compared to other automation system.

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